Combat Ration Network for Technology Transfer

QUALITY IMPROVEMENT OF CHEESE SPREAD

CORANET II STP #2018

Final Technical Report

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Cheese spread is a popular component used in the U.S. military feeding program in Meal, Ready to-Eat (MRE) rations. Currently, the military requires a 3-yr shelf life if stored at 80F. However, due to product deployment into very warm climates, it would be beneficial to improve shelf life stability so that the product can withstand higher storage temperatures. In order to provide good quality at elevated temperatures, a systematic approach to ingredient evaluation was required. Problems with the existing cheese spread include darkening, hardening, and emulsion instability during storage at elevated temperatures. These quality parameters were studied as affected by cheese age and each of four main additives: stabilizers, colorants, emulsifying salts, and vitamins (due to required fortification with C, A, B1 and B6). Effects were studied in samples produced in pilot plant (Phase 1) and in batches produced on commercial scale in Portion Pac (Phase 2). Results indicate that the greatest improvement of the product would be removal of vitamin C or all vitamins due to the increased effect of non-enzymatic browning and potential textural changes in fortified product. Partial substitution of current stabilizer with carrageenan was suggested as it maintained a softer texture throughout analysis with less overall hardening.

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Summary

Cheese spread is a popular component used in the U.S. military feeding program in Meal, Ready-to-Eat (MRE) rations. Currently, the military requires a 3-yr shelf life if stored at 80°F. However, due to product deployment into very warm climates, it would be beneficial to improve shelf life stability so that the product can withstand higher storage temperatures. In order to provide good quality at elevated temperatures, a systematic approach to ingredient evaluation was required. Problems with the existing cheese spread include darkening, hardening, and emulsion instability during storage at elevated temperatures. These quality parameters were studied as affected by cheese age and each of four main additives: stabilizers, colorants, emulsifying salts, and vitamins (due to required fortification with C, A, B1 and B6). Effects were studied in samples produced in pilot plant (Phase 1) and in batches produced on commercial scale in Portion Pac (Phase 2). Results indicate that the greatest improvement of the product would be removal of vitamin C or all vitamins due to the increased effect of non-enzymatic browning and potential textural changes in fortified product. Partial substitution of current stabilizer with carrageenan was suggested as it maintained a softer texture throughout analysis with less overall hardening.

Introduction

The cheese spread is one of the most highly accepted components in the MRE. The troops add it to their entrees and side dishes which improve their acceptability and consumption. The current cheese spread generally meets the 3 years at 80°F and 6 months at 100°F shelf-life requirements. However, if the cheese spread is exposed to heat stress above these temperatures, texture and overall quality sharply decrease. Some of the storage facilities for pre-positioned war reserves (PPRW) have climate control but the majority of storages do not. Consequently, the products are subjected to higher temperatures. The Marines and other services store many of their PPWR in areas that are not climate controlled. One of these storage areas is Okinawa. Because of this situation, the Marine Corp has requested that the MREs sent to Okinawa do not contain cheese spread. This request was implemented. Current and future rations sent to Okinawa will not contain cheese until a solution is found.

The cheese spread has been in the MRE from the beginning (early eighties) and it has not been reformulated since then. Although the specifications (MIL-C-595D, 31 March, 1975; MIL-C-595E 13 November 1990; PCR-C-039 3 September 2004) require self-life of 3 years at 80°F or 6 months at 100°F, the inspection results for the period 2003/04 indicate that cheese spread accounts for 15% of all defects in food products when tested within shelf-life period. The product defects were categorized as curdled (45 %), off-color (14 %), caked/hardened (13 %), darkened (9 %), and other (19 %). Natick has been working with the manufacturer of the cheese spread (Portion Pac) to explore new ingredients, technologies and packaging for their process. The short-term project STP#2018 was awarded to specifically target color, texture, and stability of the product with the aim to reduce browning, hardening, and phase separation.

Objectives

The overall goal of the STP#2018 was to develop formulation for cheese spread with acceptable quality after being subjected to storage conditions at temperatures above 80°F. To achieve this goal, the project focused on specific objectives to determine: (1) effect of age of cheddar cheese on browning and emulsion stability of the product; (2) effect of water-to-fat ratio on water activity, development of darkening, and emulsion stability; (3) effects of various stabilizers (gums) on product texture over time; (4) effects of different carotenoid-based colorants on stability of the product's color; (5) effects of different emulsifiers and emulsifier salts on emulsion stability; (6) effects of vitamins required for fortification of MRE cheese spread on product's color, texture and emulsion stability.

Materials and Methods

The project was conducted in two phases. During Phase 1, we evaluated effects of base ingredients and additives on the quality of the product. In Phase 2, two optimized formulations were developed based on results of the first phase, and batches of cheese spread were produced in Portion Pac on commercial scale. Quality control was conducted immediately after production, during 6 weeks at 52°C [125°F, stress conditions] and during 6-month storage at 4°C [40°F] and 38°C [100°F, accelerated storage]. Samples were further evaluated by sensory panels at University of Tennessee and at Natick.

To evaluate effects of cycling temperatures on color, texture and emulsion stability of cheese spread, samples produced in Phase 2, were additionally stored at temperatures simulating conditions in Middle East and quality was monitored over time.

Sample preparation

Effect of age of cheddar cheese

The formulation for this part of the project was not altered. The samples were taken directly from the Portion Pac's regular production line (Table 1). Sampling was coordinated with the manufacturer so that three characteristic ages of cheese were represented.

Table 1: Samples received from Portion Pac produced from cheese of various age

Age of cheese used for the spread*	Number of pouches	Date received
118	85	August 2005
162	90	August 2005
207	93	December 2005

*The cheddar cheese must be at least 90 days old.

The ingredient list on the commercial product was as follows: Cheddar cheese (milk, cheese culture, salt, enzymes), butter, water, sodium phosphate, salt, lactic acid, vitamin C, mono and diglycerides (vegetable), APO carotenal, annatto, xanthan gum, locust bean gum, guar gum, vitamins A, B6, B1.

Immediately upon arrival of each batch, the pouches were randomly assigned to storage at 4°C (40 F), 38°C (100 F), and 52°C (125 F).

Effect of moisture to fat ratio

The effect of moisture to fat ratio (42%:38%; 40%:40%; and 38%:42%) on emulsion stability during storage was investigated using formulation of cheese spread developed at UT. The formulation consisted of cheddar cheese (55%), butter (24.8, 27.3, or 29.8%), water (16.7%, 14.2, or 11.7%), trisodium phosphate (0.5%), disodium phosphate (1.5%), salt (1.3% added), lactic acid (0.22%), mono- and diglycerides (0.06%), stabilizers (xanthan, locust bean, guar gum; 0.22%). White cheddar cheese was obtained from Portion Pac, butter from a local grocery store, and both were stored at 37-40 °F until use. For each ratio, 10 lb batch of cheese spread was produced in UT FST pilot plant. The process started by chopping the cheese and butter and letting them acclimate to room temperature. Appropriate amount of water was heated to 130°F and salt and gums were mixed in. Phosphates, mono- and diglycerides were blended in and the mixture was further heated to 150 °F. Butter was mixed into the water phase and when the mixture became completely homogenized cheese was slowly added. The temperature was raised to 170°F until the blend was melted. Lactic acid was added only if necessary to achieve pH between 5.5 and 5.9. The spread was filled into the Retain Bags (Whirlpak), retorted (5 min to reach 232 °F, 1 min at 232°F, cooling to 205-208°F for 15 min), and placed into tap water to cool to about 100°F. After drying, the pouches were randomly selected and stored at 40°F (4°C), 100°F (38°C), and 125°F (52°C).

Effect of additives

Based on the results of cheese-age effects, cheddar cheese aged between 145-155 days old was used for all UT produced spreads. The flow chart outlining the general production scheme is shown in Figure 1.

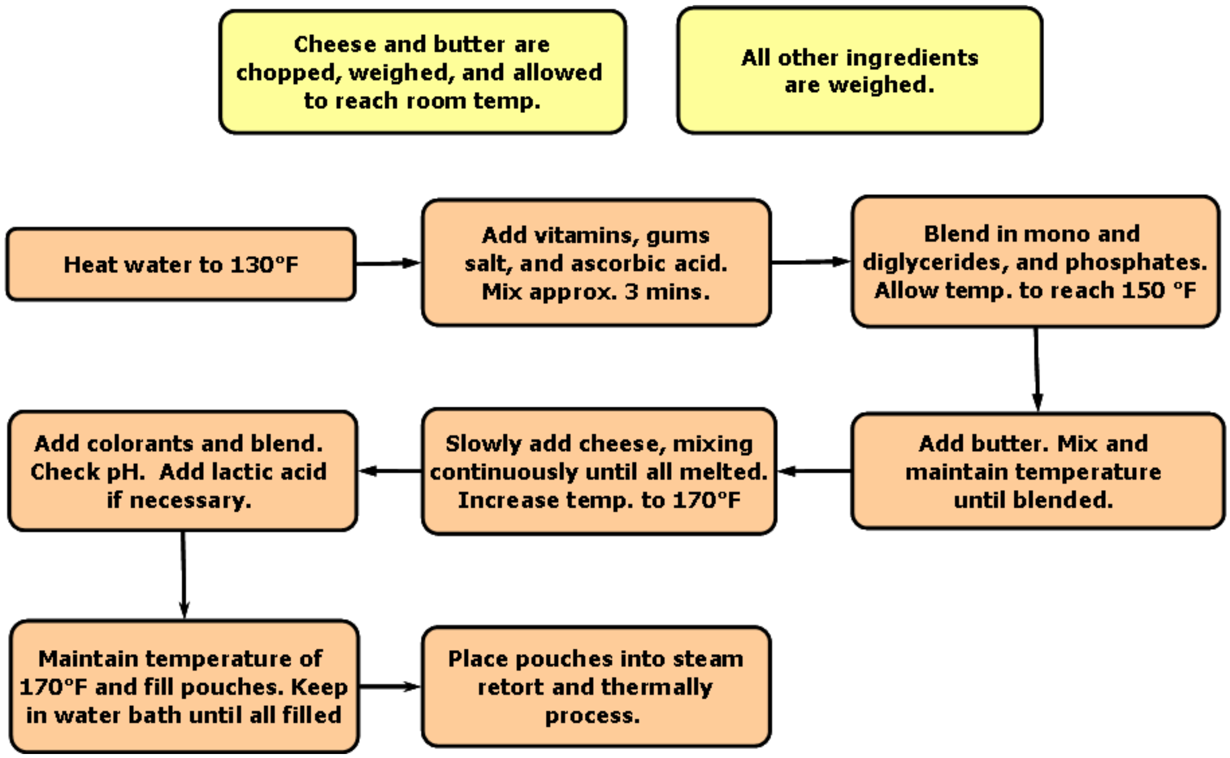

Figure 1. General production scheme used for cheese spread produced at University of Tennessee.

The cheese spread produced in the pilot plant was filled into 4 oz. Whirlpak Retain Bag (Nasco, Fort Atkinson, WI) and held at 77°C until ready for retorting. Approximately 90 pouches were packaged for each 10 lb cheese spread. The pouches were placed into the retort and steam was applied until 110°C was obtained (approx. 5 mins), then held for one minute. Steam was turned off and allowed to cool under 7 psi air pressure until it cooled to 98°C. Pouches were removed and placed in a room temperature water bath to cool. Pouches were placed into three different storage temperatures: 52°C for six-weeks (stressed shelf-life study); 4 and 38°C for six-months (refrigerated and accelerated shelf-life study, respectively).

Basic UT formulation developed for evaluation of additives is shown in Table 2. The presented formulation served as control and was produced with each experiment. For evaluation of stabilizers standard gums were replaced with the same amount (0.22%) of xanthan, low methoxy pectin, and carrageenan or the samples were produced with reduced (0.11%) amount of standard stabilizers (CP Kelko gum mixture for cheese spread). Stability of color was investigated by replacing standard colorant mixture (APO-carotenal and annatto) with APO-carotenal, annatto, and paprika oleoresin. Colorants were added in the same amount as in control. Effects of emulsifying salts were determined replacing standard 1.5% disodiumphosphate (DSP) and 0.5% trisodiumphosphate (TSP) with 2% citrates or with 1% DSP and 1% TSP. Role of vitamins on product quality was investigated by producing samples with no

vitamins, eliminating only vitamin C (still added vitamins A, B1, and B6 in regular amounts), and adding 10 times higher amount of vitamin C (with no other vitamins).

Table 2. Cheese spread formulation developed at UT FST and used for evaluation of additives

Ingredient	Weight (g)	Weight (%)	Military Specs	Comments
Cheese	2497	55.0	At least 51% cheese by weight	This combination of cheese, butter and water averages ~42% moisture by analysis. Calculated for 38% fat and 42% moisture.
Butter (salted)	1125	24.8		
Water	758	16.7		
Trisodium Phosphate	22.7	0.5	Not less than 1.9% nor more than 3% by weight	Consulted with industry representatives for amount generally found in similar products.
Disodium Phosphate	68.1	1.5		
Salt (added)	60	1.3	Not less than 1.6% nor more than 2.5%	Dependent upon salt contributed from cheese and butter.
Lactic Acid (88%)	10	0.22	pH between 5.5 and 5.9	Lactic acid added to adjust pH (not necessary for all batches).
Vitamin C (added as Ascorbic Acid)	4	0.09	Not less than 38 mg per pouch	Meets requirement.
Mono- and Diglycerides	2.27	0.06	Not more than 0.5%	Estimate based on industry consultation.
Stabilizers (Xanthan, Locust Bean, Guar Gums)	10	0.22	Not more than 0.3%	Combination gum supplied by CP Kelco.
APO-carotenal (2%)	3.5 mL		At least 2% carotenal and bixin.	Used in combination to satisfy color requirement.
Annatto (2% bixin)	3.5 mL		Use as needed to conform color	
Vitamin A	0.14	0.003	Not less than 800 retinol units	Added to comply with product requirements.
Vitamin B6	0.10	0.002	Not less than 0.80 mg per pouch	
Vitamin B1	0.1	0.002	Not less than 1.0 mg per pouch	

Storage

A shelf-life of 3-yrs at 80°F (26°C) is required for MRE's and government verification may include storage testing using the shorter, higher temperature schemes to obtain stability results. The high temperature treatments were chosen based on military reports that major defects occur after storage at temperatures exceeding 38°C (DPSC 1997). Cheese spread samples were studied for time-temperature effects. For first six weeks of storage, three pouches from 52°C storage were taken weekly and analyzed. Samples stored at 4 and 38°C were sampled monthly during 6 months. All samples were analyzed for texture, color, water activity, emulsion stability, pH and moisture. Cheese spread pouches were acclimated to room temperature for approximately 2 hrs prior to analysis. All analyses were performed on non-kneaded samples. Portions of each pouch were divided and used in the obtaining the physical parameters. Remaining cheese spread was stored at -40°C for future chemical analysis.

Standard test to determine shelf-life of a product includes quality evaluation at accelerated (38 °C, 100 °F) or stress (52 °C, 125 °F) temperatures for 6 months or 6 weeks, respectively. However, although some products, such as cheese spread, pass the accelerated test, they rapidly degrade in desert storages where temperatures fluctuate from 85°F (30°C) to 130°F (55°C) within 24 hours. Thus, in Phase 2, we included additional storage regime – cycling temperatures, to simulate storage conditions in desert areas in Middle East. The storage conditions were: start at 30 °C, ramp up by 4 °C/hr for 5 hrs, hold at 50 °C for 5 hrs, ramp down by 1.43 °C/hr for 14 hrs (Figure 2, red line). The 24-hrs temperature cycle was repeated during 6 months.

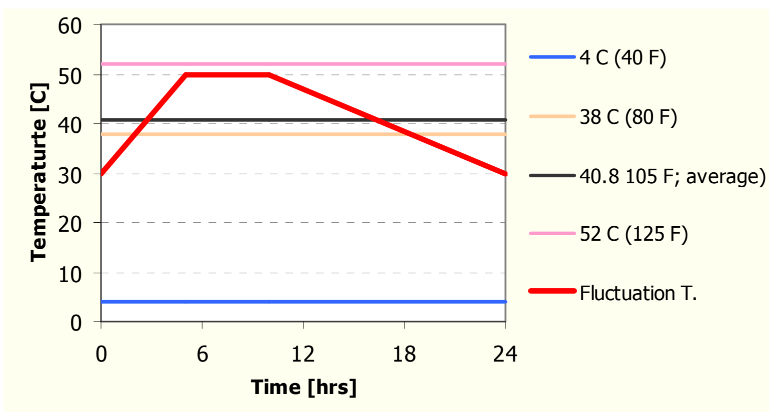

Figure 2. Cycling temperature diagram

Quality Evaluation

Samples stored at 4 °C and 38 °C were analyzed monthly during 6 months and those stored at 52 °C weekly during 6 weeks. At each sampling day, samples were analyzed for texture, color, water activity, emulsion stability, pH and moisture. Cheese spread pouches were acclimated to room temperature for approximately 2 hrs prior to analysis. The pouch was not kneaded. The appropriate amount of cheese was then divided for the following physical analyses:

Texture: Three 7.5 g replications were cut from each packet and gently spread into small plastic cups, also used for water activity. Samples were analyzed on the TA.XT*Plus* Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK) using Texture Exponent 32 software version 2.06. The CHE3/P1S application for firmness and stickiness of cheese

spread was loaded, using a test speed of 2.5mm/sec with compression at 50%. A 25-mm diameter cylinder probe was used.

Color: One 7.5 g sample from each packet was measured for color using the Hunter Lab MiniScan XE Plus (Hunter Associates Laboratory, Reston, VA) after calibration using a black and white tile. L*, a*, and b* values were recorded using the "Colorant Strength D/65" setting. L-values measure lightness to darkness on a scale of 0 (black) to 100 (white); a* values are positive (redness) to negative (green); b* values are positive (yellow) to negative (blue).

Emulsion Stability: A single 5 g sample was cut from the middle of each cheese spread pouch and placed in a centrifuge tube. The Sorvall RC 5B Plus centrifuge (ThermoElectron Corp., Asheville, NC) is set at 10,000 rpm (~11,900g) for one hour. If phase separation occurred, the upper liquid phase was removed and the percent weight loss was recorded.

Water Activity: Again, one 7.5 g sample from each packet was measured using the a the Aqualab Series 3 meter (Decagon Devices Inc., Pullman, WA) after calibration with factory standards of 0.760 and 0.984.

pH: A 5 g sample from each packet was cut from the remaining cheese spread, placed in a plastic tube with 10mL water and homogenized form ~30 sec. The pH of the sample is then measured with the Accumet Basic AB15 meter (Fisher Scientific).

Moisture Analysis: Three 2.5 g samples from three packets were measured gravimetrically after 5 hrs at 100°C.

Sensory Evaluation

Sensory evaluation was performed on the optimized formulations (Phase 2) having standard Portion Pac's product as a control. Three batches were (a) standard Portion Pac's formulation (control); (b) standard Portion Pac's formulation with no vitamins, and (c) standard formulation with no vitamins and altered stabilizers (0.1% standard gum mix plus 0.1% carrageenan). Sensory testing used of consumer panel. There were 100 panelists that sampled each of the three cheese spreads. Majority of panelists lacked familiarity with the product and only a few associated it to a "snack pack" type cheese product. The majority of the panelists were between 20-59 years old and not involved in the armed services. The samples were presented in succession with several questions pertaining to appearance, color, flavor, and overall liking. The responses were based on a nine-point hedonic scale where a 1=dislike extremely and a 9= liked extremely. Responses were averaged and a score between one and nine assigned.

Results and Discussion

Effect of age of cheddar cheese

The cheese spread samples received from Portion Pac were evaluated immediately upon arrival. The quality parameters are shown in Table 3 and these values served as control for appropriate 'cheese age' samples. The batches were different in regard to color (L values from 75.30 to 78.15) and texture (hardness from 0.504 to 0.836). Moreover, in-house sensory evaluation also showed differences between samples: cheese spread produced with 118 days old cheese was smooth and creamy, salty, and with strong aftertaste; 162-d cheese spread was creamy, with slight cooked flavor, and was mildly salty, while 207-d sample was very creamy, had over-cooked flavor, and buttery aftertaste. These differences may be partially due to age of the cheese but more likely due to slight variations in formulation. For example, since the gums are generally added in very low concentration it is easy to cause a significant deviations in texture of the final product due to minute variations in quantity of the stabilizers used.

Table 3: Quality parameters of cheese spread produced with 118 days old cheddar cheese and stored at 4, 38, and 52 °C

	L*	a*	b*	pH	aw	Hardness	Adhesive	Moisture %
118d d	77.68	17.63	46.92	5.88	0.950	0.836	-0.602	39.39
162 d	78.15	18.05	49.63	5.82	0.959	0.504	-0.447	39.89
207 d	75.30	20.16	49.66	5.93	0.947	0.592	-0.407	41.31

The military feeding program reports the greatest defects of this product during storage are hardening and darkening, thus the discussion will be focused on the textural (firmness) and color (L-value) measurements. The 207 day old cheese had a significant decrease in L-value (more darkening) than did the younger and middle-aged cheese spreads Table 4, Figure 3). Temperature storage for six month was significant to the firming or darkening of the spreads. At each temperature, differences between firmness and L-values were observed. At 4°C the middle-aged cheese darkened least and had similar firmness to the young cheese. At 38°C there was no significant difference in L-value for the young and middle cheeses, however, the oldest cheese darkened significantly more. Although in both temperatures the oldest cheese hardened the least, it did show emulsion instability throughout analyses. pH and water activity experience little to no change during analysis from initial to final sampling. Also, separation was either not observed or the separated liquid was too minimal to separate from the centrifuged sample for the young and middle-aged cheeses. However, measurable separation occurred during analysis for the 207 day old cheese. Following are summarized effects of cheese age on color, texture and emulsion stability:

Effects on color:

- Middle aged cheese (162 d) maintained a better color stability than young (118 d) and old (207 d) aged cheeses;
- Of those samples stored at 38 °C, young (118 d) and middle (162 d) aged cheeses showed considerable darkening after 6 months but old (207 d) cheese-samples darkened already after 4 months;
- Regardless on the age of the cheese, L-value decreased faster when the product was stored at higher temperatures (52 °C [125 °F] > 38 °C [100 °F] > 4°C [40 °F]);
- Samples stored at 4 °C apparently did not darken;

- L-values were similar in samples stored at 38 °C for 6 months and at 52 °C for 6 weeks (118-d: 68.67 and 67.72; 162-d: 73.97 and 70.90; 207-d: 64.20 and 66.20, respectively);
- a-value (redness) did not change in samples with young (118 d) and old (207 d) cheese, regardless on temperature of storage;
- in spread produced with middle aged (162 d) cheese, a-value did not change in the product stored at 4 °C but it slightly decreased when stored at higher temperatures. No difference was observed between samples stored at 38 °C and 52 °C;
- b-value (yellowness) did not change in samples stored at 4 °C for 6 months regardless on age of cheese. However, in samples stored at 38 °C and at 52 °C the values decreased. In young (118 d) and old (207 d) cheese samples decrease in b-value was similar at 38 °C and 52 °C. However, in the samples produced with middle (162 d) aged cheese the decrease was at the greater rate at 52 °C than at 38 °C;
- The decrease in b-value may have two visible consequences: (a) if no other color changes occurred, the cheese spread will appear pale; or (b) if the browning reactions happen, darkening would be more visible than in more yellow samples. The decrease in b-value is probably the result of degradation of bixin, the main chromophore in annatto.

Effect on texture:

- Generally, the cheese spread hardened over time;
- When spread was stored under accelerated storage conditions (52 °C), samples produced from young cheese toughened faster then spread produced with mid and old cheddar cheese;
- The spread produced with mid (162 d) and old (207 d) cheddar cheese hardened at approximately same rate in first 6 weeks of storage regardless on the storage temperature;
- Overall, adhesiveness did not change during storage. Only samples with mid-aged cheese (162 d) stored at 4 °C for 3 and 4 months appeared to be more ‘sticky’.

Effect on emulsion stability:

- None or minimal phase separation observed with young and middle-aged cheese. Cheese spread prepared with old (207 d) cheese showed separation at all storage temperatures regardless on length of storage.

Based on changes in firmness, darkening, and emulsion stability, a **middle age cheese (150-170 days aged)** was selected for use in the laboratory production of cheese spread as it showed greatest stability of those tested.

It should be kept in mind, for these and all other samples/treatments, that values for firmness are higher in samples stored at 38°C for 6 months than in samples stored 6 weeks at 52°C, indicating that hardening, although accelerated at higher temperatures, still needs time to fully develop. On the other hand, darkening is predominantly affected by temperature and L-values of samples kept for 6 weeks at 52°C are similar or lower than for those kept 6 months at 38°C.

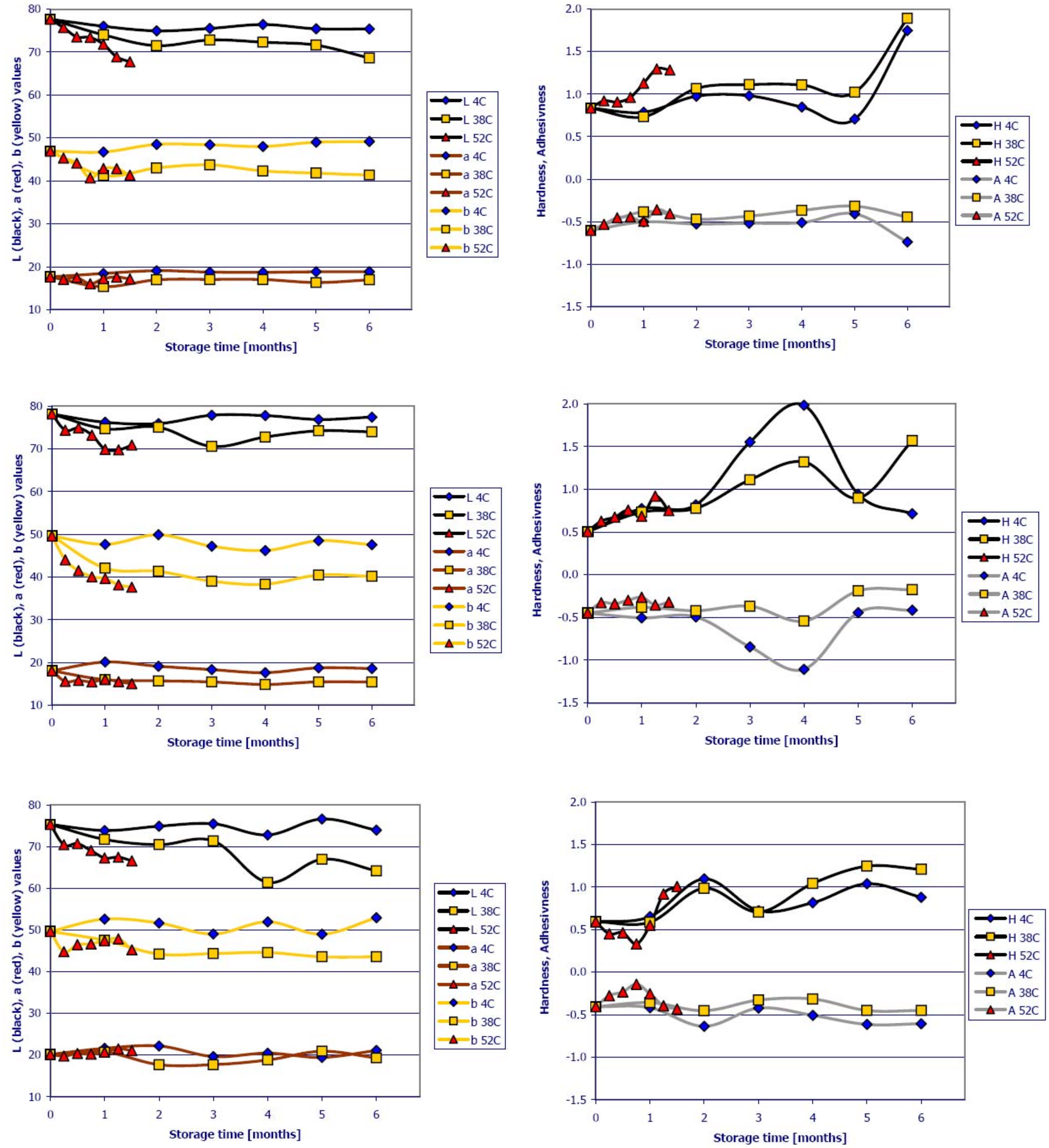

Figure 3: Color (left) and texture (right) changes of parameters of cheese spread produced with 118 (top), 162 (middle), and 207(bottom) days old cheddar cheese and stored at 4, 38, and 52 °C. [H-hardness; A-adhesiveness]

Table 4. Quality parameters of cheese spread prepared with cheddar cheese of three different age (ripening time of 118, 162 and 207 days) stored for 6 weeks at 52°C, and 6 months at 4 and 38°C

Storage	Treatment	L-value	Firmness [kg]	pH	Aw	Emulsion Stability/ Separation (%)
4°C / 6 m	118 d	75.41	1.747	5.84	0.962	~11
	162 d	73.69	0.713	6.02	0.942	Minimal
	207 d	73.90	0.879	6.17	0.949	0.83 ± 0.18
38°C / 6m	118 d	68.63	1.890	5.84	0.956	No separation
	162 d	74.25	1.568	5.83	0.950	No separation
	207 d	64.20	1.208	5.93	0.953	Minimal
52°C / 6w	118 d	67.72	1.283	5.86	0.950	No separation
	162 d	70.90	0.751	5.90	0.955	No separation
	207 d	66.58	1.007	5.80	0.947	0.90 ± 0.03

Effect of moisture to far ratio

Only spread with 42 % moisture and 38 % fat was possible to produce in our pilot plant. In the other two attempts to produce cheese spread with less water, the cheese could not be blended sufficiently well and the product was too thick to be pumped and properly packaged. The formulation with 42:38 moisture to fat ratio is determined to be our standard (control) batch and will be used in the future experiments.

Effects of stabilizers

Data presented in Figure 4 show the trend for firmness and L-value throughout the six-week (52°C) and six-month (4 and 38°C) storage periods.

In the elevated temperatures, firmness increased over storage time while minimal changes are observed in the refrigerated temperature. L-values decreased, or samples darkened, in the elevated temperatures and remained relatively unchanged in cold storage.

- **All samples with altered stabilizers had more soft texture upon production when compared with control**, and although hardened during storage, were still less hard (lower firmness values) than control (Table 5).
- **Samples with carrageenan had smooth and more soft texture** than samples with any other gum, or even samples with only half of standard gum mixture (LMG).
- As seen in previous instances, the pH and water activity remained constant in initial and final values.
- Phase separation was observed at 4°C for all samples except that of the control. In addition, samples with carrageenan (CAR) exhibited minimal emulsion instability after six-months at 38°C.

Table 5. Quality parameters of cheese spread prepared with different stabilizers (4BCON=control; CAR=carrageenan; LMG=lower mixed-gums; LMP= low-methoxy pectin; XAN=xanthan) stored for 6 weeks at 52°C, and 6 months at 4 and 38°C

Storage	Treatment	L-value	Firmness [kg]	pH	Aw	Emulsion Stability/ Separation (%)
4°C / 6 m	4BCON	73.97	1.116	5.83	0.951	No Separation
	CAR	70.77	0.511	5.99	0.953	5.06 ± 0.48
	LMG	72.12	0.605	5.67	0.941	3.09 ± 0.68
	LMP	71.45	0.618	5.92	0.948	4.88 ± 0.59
	XAN	72.15	0.637	5.76	0.954	4.40 ± 0.36
38°C / 6m	4BCON	58.49	>5.6	5.70	0.891	No Separation
	CAR	58.72	2.758	5.63	0.923	0.68 ± 0.42
	LMG	57.24	4.030	5.50	0.913	No Separation
	LMP	58.00	4.751	5.63	0.906	No Separation
	XAN	60.20	4.449	5.60	0.913	No Separation
52°C / 6w	4BCON	58.56	3.114	5.76	0.919	No Separation
	CAR	56.21	2.299	5.79	0.940	No Separation
	LMG	54.79	2.853	5.69	0.925	No Separation
	LMP	56.26	2.683	5.71	0.914	No Separation
	XAN	57.84	2.719	5.72	0.931	No Separation

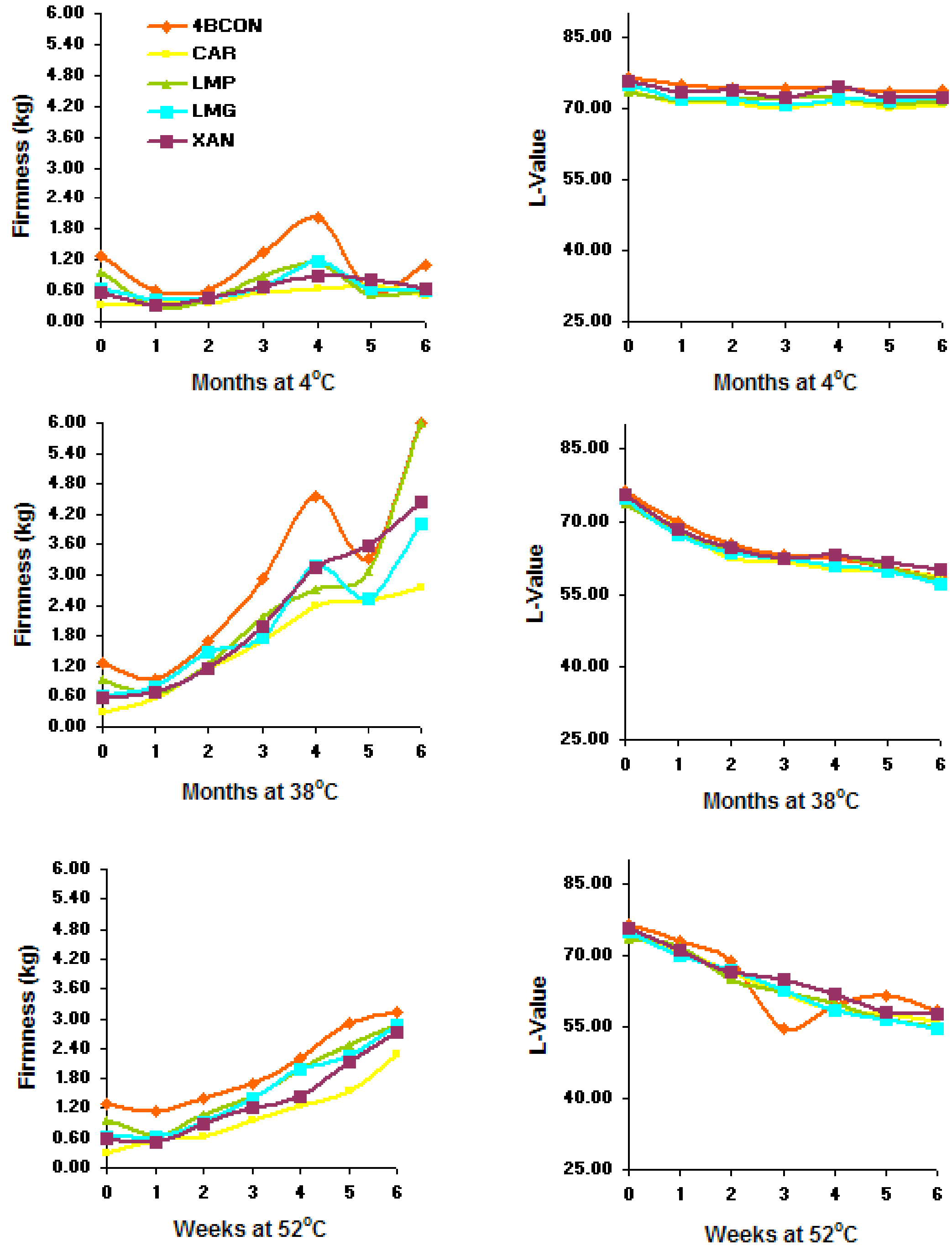

Figure 4. Texture and L-value color data for (A) 52°C for six weeks, and (B) 38°C and (C) 4°C for six months of batches used in stabilizer comparisons. (4BCON=control; CAR=carrageenan; LMG=lower mixed-gums; LMP= low-methoxy pectin; XAN=xanthan)

Effects of colorants

Figure 5 shows the overall trends in both firmness and L-value changes at 52, 38, and 4°C over six-week or six-month storage. The maintenance of the cheese color was a primary indicator for stability. The military requirement for color suggests an L-value between 69.00 and 76.80 based on a national cheese color standard.

- For all the colored samples, L-values were unacceptable just after two weeks at 52°C and one month at 38°C. All refrigerated samples were deemed acceptable.
- Although all samples hardened during storage, **no particular effect of colorants was detected on textural changes.**
- Samples with **paprika oleoresin (PO) darkened less** compared to control and those with annatto and apo-carotenal alone; however, PO samples had a slightly pinkish hue.
- The pH and water activity remained constant in initial and final values.
- Phase separation was observed only in samples stored at 4°C except that of the control.

Table 6. Quality parameters of cheese spread prepared with different colorants (4BCON=control; NCL=no color; APO=apo-carotenal; ANT=annatto; PO=paprika oleoresin) stored for 6 weeks at 52°C, and 6 months at 4 and 38°C

Storage	Treatment	L-value	Firmness [kg]	pH	Aw	Emulsion Stability/ Separation (%)
4°C / 6 m	4BCON	73.97	1.116	5.83	0.951	No separation
	NCL	85.40	0.774	5.75	0.953	2.52 ± 0.40
	ANT	74.16	0.792	5.87	0.950	3.44 ± 0.97
	APO	73.71	0.844	5.81	0.947	1.55 ± 0.51
	PO	73.54	1.000	5.78	0.946	0.82 ± 0.19
38°C / 6m	4BCON	58.49	>5.6	5.70	0.891	No separation
	NCL	65.79	4.848	5.70	0.901	No separation
	ANT	58.02	>5.6	5.68	0.893	No separation
	APO	59.01	>5.6	5.70	0.901	No separation
	PO	62.02	4.809	5.67	0.917	No separation
52°C / 6w	4BCON	58.56	3.114	5.76	0.919	No separation
	NCL	60.45	2.929	5.82	0.925	No separation
	ANT	56.56	3.132	5.88	0.917	No separation
	APO	57.05	3.606	5.76	0.914	No separation
	PO	61.09	2.943	5.76	0.920	No separation

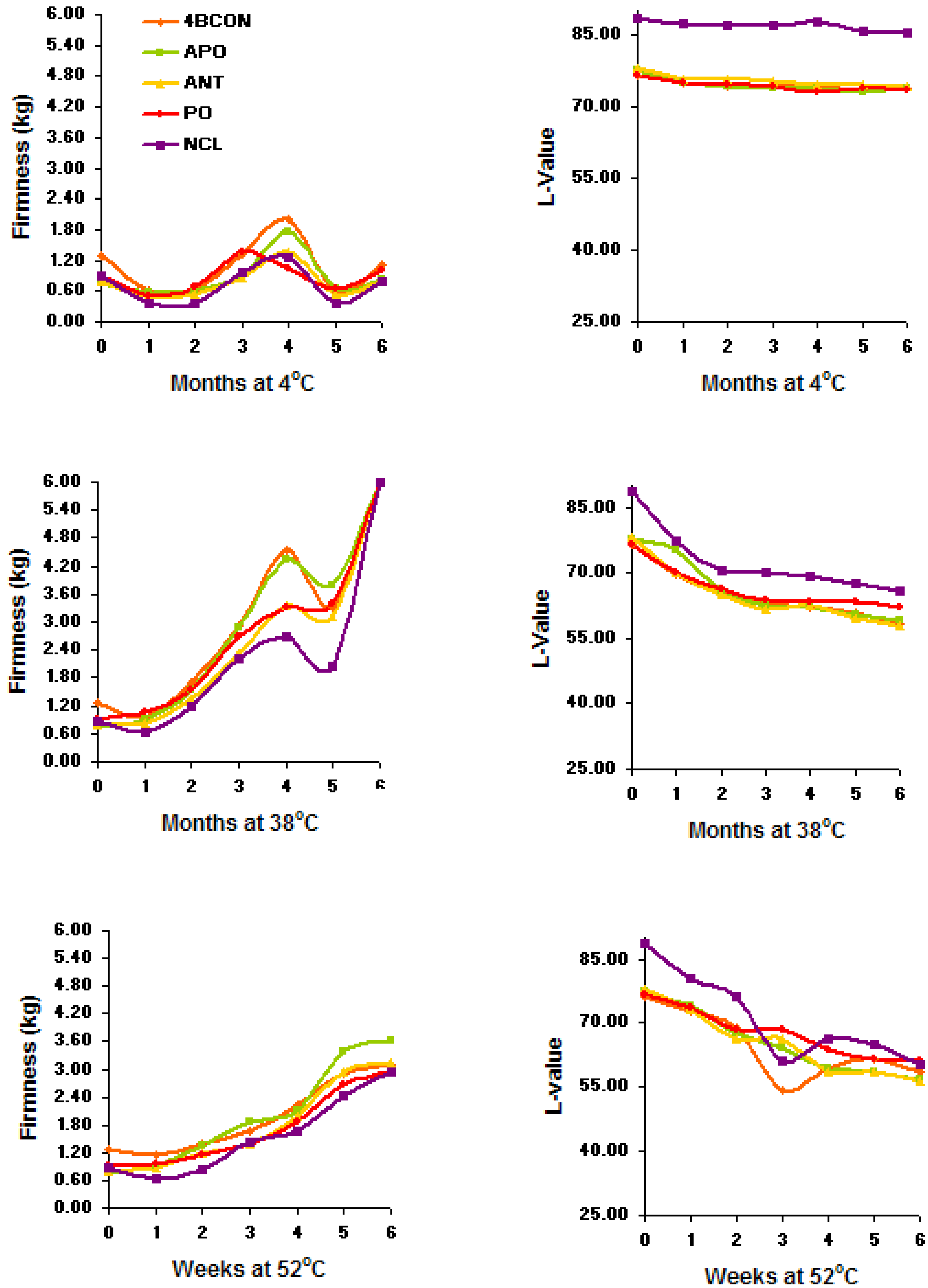

Figure 5. Texture and L-value data for in-house produced cheese spread (A) 52°C for six weeks, and (B) 38°C and (C) 4°C for six months of batches used in colorant comparisons.

(4BCON=control; APO=apo-carotenal; ANT=annatto; PO=paprika oleoresin; NCL=no color)

Effects of emulsifying salts

Figure 6 shows trend of color and texture changes in samples with altered emulsifying salts - citrates (2%; "CIT") and adjusted phosphate mix (1% of each DSP and TSP; "LP") compared with control (1.5%DSP and 0.5% TSP, "4BCON").

- When stored at 4 and 38°C all samples showed similar trend in textural changes. However, when stored at 52°C **samples with 2% citrates (CIT) hardened significantly more** than those with di- and tri-sodium phosphates (LP and control).
- All samples darkened by similar trend and it appeared that **emulsifying salts did not have effect on changes in color.**
- The emulsion was stable for the control after storage in all temperatures but separation was observed after six months at 4°C for samples with citrates (CIT) and altered levels of phosphates (LP) (Table 7).

Although the citrates and phosphates have similar ionic components, the attractive forces between the surface of the cheese and other components will affect the rate of protein aggregation and emulsification. In general, for processed cheeses, phosphates have greater calcium sequestration than do the citrates; however, phosphates possess greater buffering capacity in the range of cheese spread (pH=5.5-6.0) and the more acidic citrates tend to produce crumbly spreads (Fox et al., 2000). This can potentially explain the behavior observed after six weeks in the stressed environment of 52°C. The effect of the emulsifying salts is difficult to discern based on the complex environment present in the cheese spread

Table 7. Quality parameters of cheese spread prepared with different emulsifiers (4BCON=control; CIT=citrate; LP=adjusted phosphate mix) stored for 6 weeks at 52°C, and 6 months at 4 and 38°C

Storage	Treatment	L-value	Firmness [kg]	pH	Aw	Emulsion Stability/ Separation (%)
4°C / 6 m	4BCON	73.97	1.116	5.83	0.951	No Separation
	CIT	71.92	1.035	5.72	0.954	1.08 ± 0.28
	LP	72.02	0.611	5.70	0.950	3.94 ± 0.60
38°C / 6m	4BCON	58.49	>5.6	5.70	0.891	No Separation
	CIT	58.29	5.577	5.69	0.923	No Separation
	LP	55.58	4.327	5.50	0.916	No Separation
52°C / 6w	4BCON	58.56	3.114	5.76	0.919	No Separation
	CIT	59.41	>5.6	5.74	0.934	No Separation
	LP	55.26	2.683	5.81	0.932	No Separation

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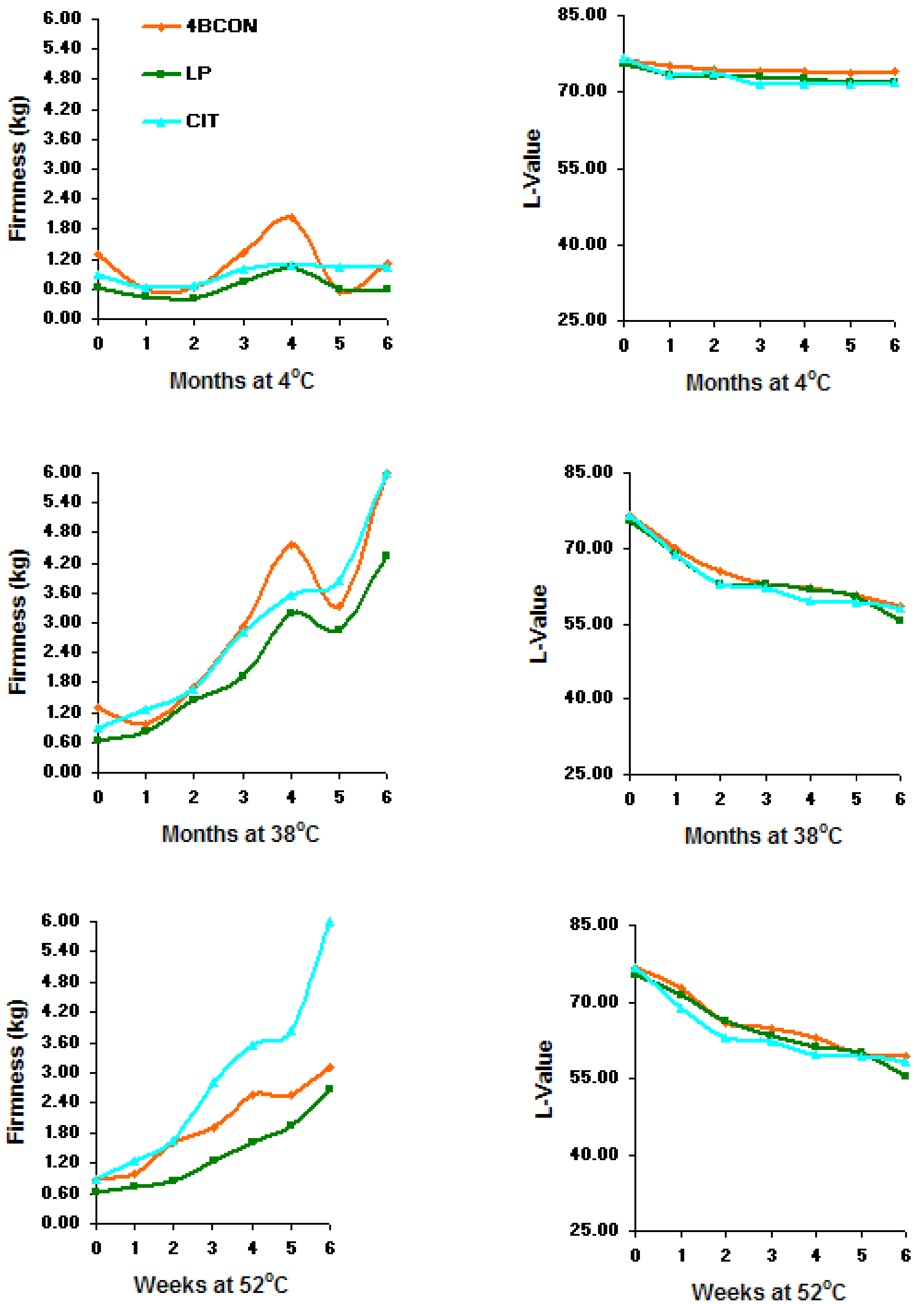

Figure 6. Texture and L-value color data for (A) 52°C for six weeks, and (B) 38°C and (C) 4°C for six months of batches used in emulsifying salt comparisons. (4BCON=control; CIT=citrate; LP=adjusted phosphate mix)

Effect of vitamins

The guidelines for cheese spread fortification include the addition of retinol (vitamin A), thiamine (vitamin B1), pyridoxine (vitamin B6), and ascorbic acid (vitamin C). There were four batches produced which include the following: (4CON) a control, which satisfies minimum requirements for all required vitamins; (CON40) excess ascorbic acid, which included 10 times more ascorbic acid than control with other vitamins in required quantities; (VNC) no ascorbic acid added but other vitamins added in required quantities; and (NV) no vitamins added. Trends for firmness and L-value during storage are presented in Figure 7. Overall quality after storage is given in Table 8.

- Similar to other treatments, samples stored at 4°C did not change much in color in texture.
- Samples with 10x higher vitamin C concentration (CON40) rapidly darkened and became unacceptable after only 1 week at 52°C or 1 month at 38°C.
- **Samples with no vitamins (NV) darkened the least at 52°C** (L-value 71.70 vs. 68.70 in VNC and 61.89 in control), while **at 38°C color of 'no vitamins' (NV) samples and those with omission of only vitamin C (VNC) was similar but better than control** (NV 68.94, VNC 69,12 vs. 4CON 64.40).
- Too much vitamin C (CON40 samples) resulted in rubbery texture after 6 weeks at 52°C.
- pH remained within the required range and water activity varied slightly.
- No separation observed in these analyses.

Therefore, it may be suggested that the greatest effect in product stability under these conditions may be the removal of vitamins or just vitamin C.

Table 8. Quality parameters of cheese spread prepared with different levels of vitamins (4CON=control; CON40=control with 10x vitamin C added; NV=no vitamins added; VNC= vitamins other than C added) stored for 6 weeks at 52°C, and 6 months at 4 and 38°C

Storage	Treatment	L-value	Firmness [kg]	pH	Aw	Emulsion Stability/ Separation (%)
4°C / 6 m	4CON	76.44	1.137	5.63	0.951	No separation
	CON40	76.49	1.541	5.66	0.955	No separation
	NV	77.60	1.105	5.98	0.955	No separation
	VNC	77.82	1.508	6.05	0.949	No separation
38°C / 6m	4CON	64.40	4.783	5.63	0.925	No separation
	CON40	29.57	>5.6	5.63	0.909	No separation
	NV	68.94	5.452	5.78	0.918	No separation
	VNC	69.12	>5.6	5.76	0.896	No separation
52°C / 6w	4CON	61.89	3.150	5.52	0.936	No separation
	CON40	44.57	>5.6	5.36	0.928	No separation
	NV	71.70	3.413	5.56	0.918	No separation
	VNC	68.70	4.757	5.59	0.919	No separation

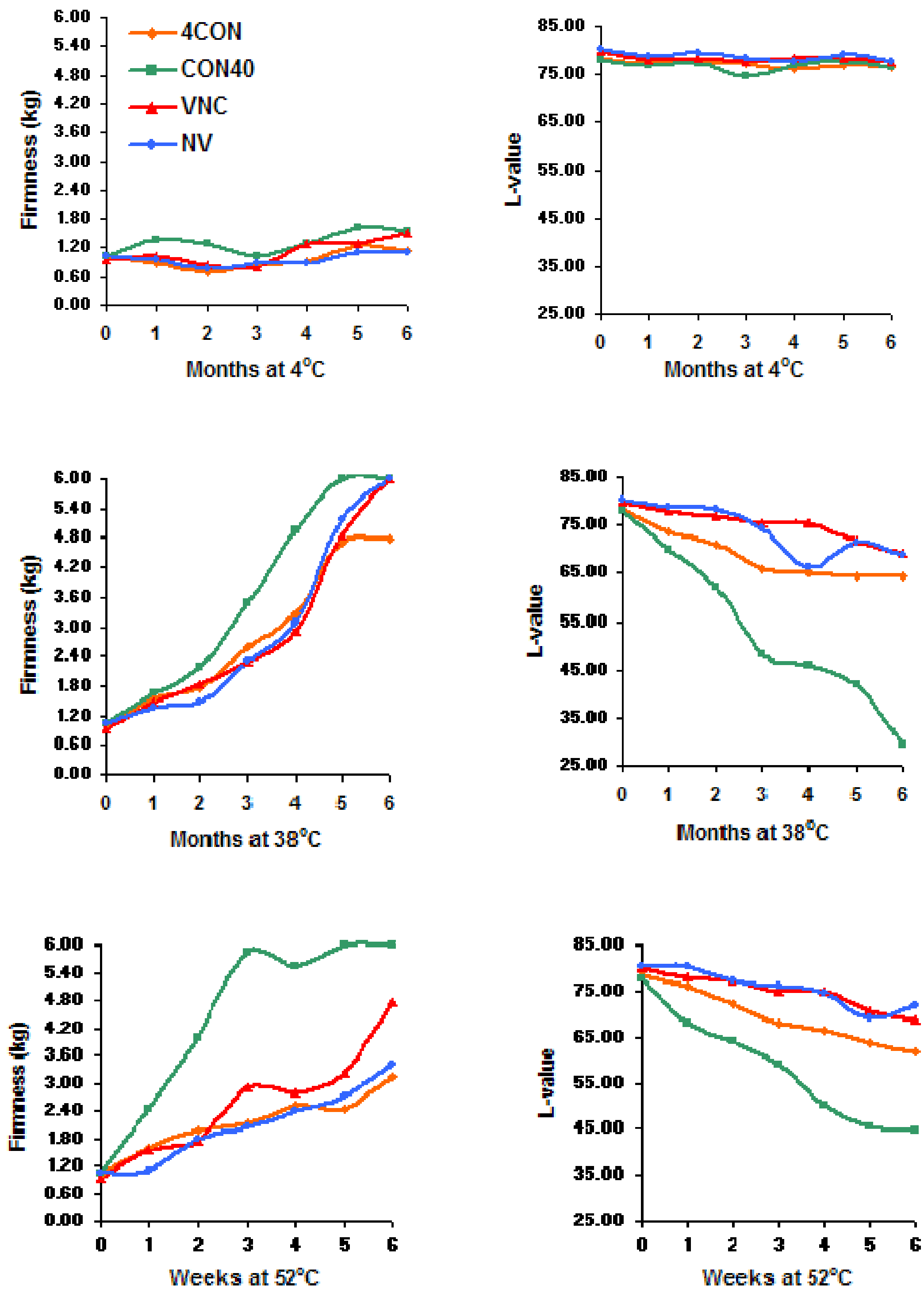

Figure 7 Texture and L-value data for in-house produced cheese spread (A) 52°C for six weeks, and (B) 38°C and (C) 4°C for six months of batches used in vitamin comparisons. (4CON=control; CON40=control with 10x vitamin C added; VNC= vitamins other than C added; NV=no vitamins)

Optimized formulations

To summarize the individual analysis of the four classifications of additives studied are: (1) vitamin removal will lessen the amount of darkening and hardening observed during storage; (2) minimal effect on firmness or darkening was observed with the colorants; and (3) the use of carrageenan as the stabilizer resulted in a less firm product as compared with the other stabilizers. From these conclusions, two major formulary changes were suggested.

The current commercial formulation was used as the base recipe and our suggested changes were applied. A total of three batches were produced, the first being a batch of the presently used commercial formulation. This was designated as the standard formulation (STD). The second formulation was produced with no added vitamins (NV); and the third formulation was with no added vitamins, and standard gums were partially substituted with carrageenan (GN) (Table 9).

Table 9. Formulations of batches produced at Portion Pac* (December 2006)

Batch	Formulation
STD	**Portion Pac standard formulation**
NV	**All vitamins omitted from standard formulation**
GN	**All vitamins omitted from standard formulation and half of standard gum mix replaced with carrageenan**

**Portion Pac's formulation was confidential during the project; Alterations in formulation proposed by University of Tennessee team were applied without revealing the standard formulation*

All analyses were performed as described previously, however, due to concern by military inspectors that the fluctuation of temperature on a daily basis may have an effect on product stability, an additional temperature scheme was observed. This involved the ramping up and down of temperature from 30 to 50°C over 24 hrs.

Values for color, texture, pH, water activity and emulsion stability are shown in Table 10. Figure 8 shows the trend of texture and color changes for STD, NV, and GN during storage.

- Samples with no vitamins (NV) and with altered stabilizers and no vitamins (GN) darkened to lesser extent compared to control (STD), regardless on storage temperature (at 38°C NV 76.28, GN 76.32 vs. STD 71.50; at 52°C NV 71.23, GN 71.86 vs. STD 68.90)
- Samples with optimized formulations were less hard after 6 months at 38°c and after 6 weeks at 52°C compared to control
- Samples stored at cycling temperatures between 30 and 50°C degraded less than those stored at constant 52°C for the same time
- All batches remained in an acceptable L-value range for the temperature cycled, 4 and 38°C storage conditions, while the STD formula was the only one to drop below an acceptable L-value at the final time point of the 52°C storage.
- In all three batches, no emulsion separation occurred and pH and water activity were maintained from initial to final analyses.

Table 10. Quality parameters of cheese spread prepared based on optimized formulations (STD=standard/control; NV=no vitamins added; GN=partial gum substitution and no vitamins added) stored for 6 weeks at 52°C, and 6 months at 4 and 38°C

Storage	Treatment	L-value	Firmness [kg]	pH	Aw	Emulsion Stability/ Separation (%)
4°C / 6 m	STD	78.50	1.530	5.72	0.961	No Separation
	NV	79.97	1.227	5.91	0.963	No Separation
	GN	79.91	0.894	5.87	0.964	No Separation
38°C / 6m	STD	71.50	2.398	5.62	0.959	No Separation
	NV	76.28	1.815	5.73	0.958	No Separation
	GN	76.32	1.807	5.71	0.960	No Separation
52°C / 6w	STD	68.90	4.102	5.54	0.950	No Separation
	NV	71.23	2.848	5.64	0.946	No Separation
	GN	71.86	3.393	5.63	0.946	No Separation
Cycl.Temp. / 6 w	STD	73.62	1.734	5.56	0.950	No Separation
	NV	75.55	1.526	5.64	0.947	No Separation
	GN	76.92	1.224	5.64	0.954	No Separation

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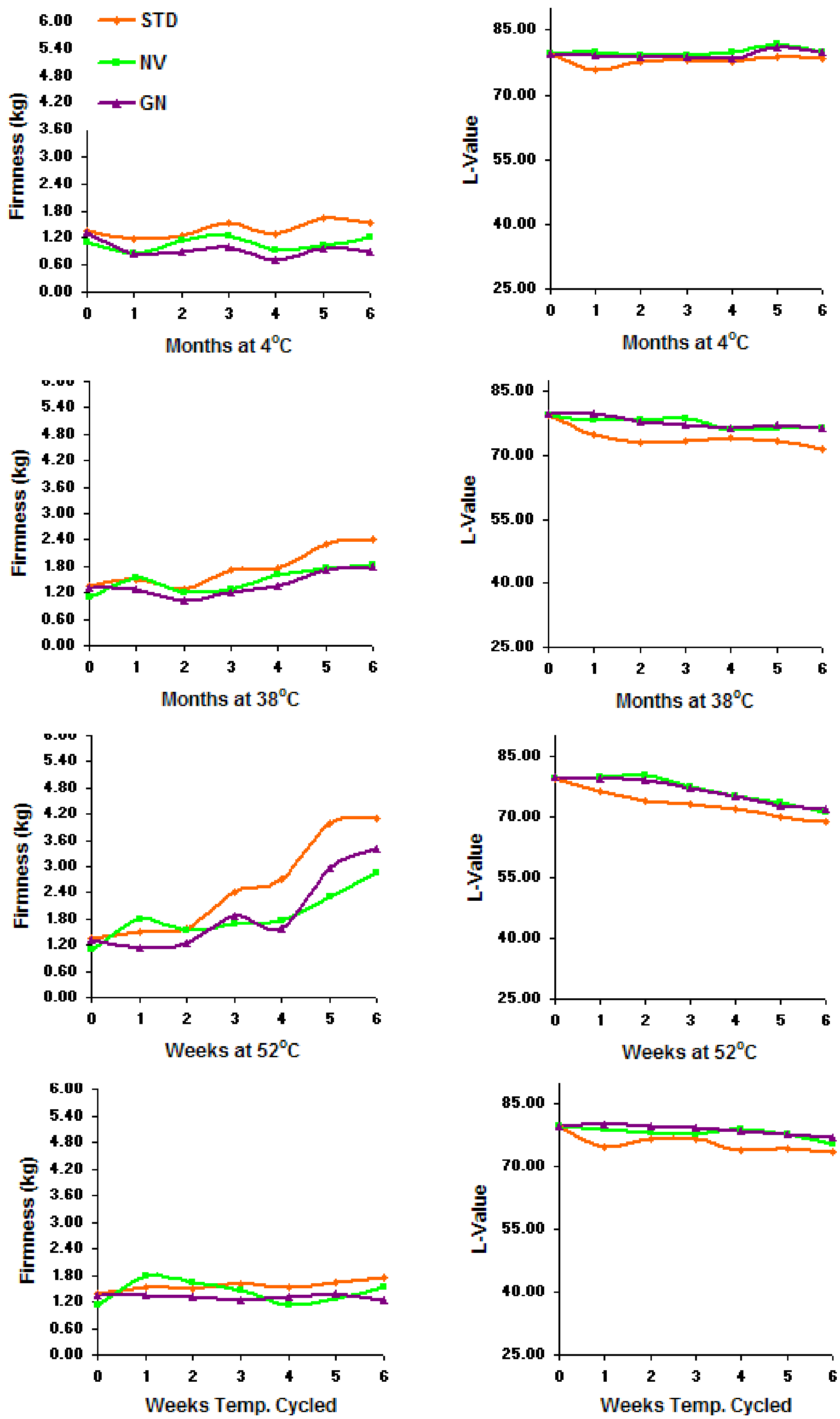

Figure 8. Texture and L-value color data for 4, 38, 52°C and temperature cycled for six weeks of batches made with suggested formulation changes. (STD=standard/control; NV=no vitamins added; GN=partial gum substitution and no vitamins added

Sensory evaluation

Results of hedonic test preformed with 100 panelists that sampled each of the three cheese spreads, are given in Table 11. The samples were presented in succession with several questions pertaining to appearance, color, flavor, and overall liking. The responses were based on a nine-point hedonic scale where a 1=dislike extremely and a 9= liked extremely. Responses were averaged and a score between 1 and 9 assigned.

Table 11. Results of nine-point hedonic sensory test for three formulations of cheese spread

Attributes	Samples		
	STD	NV	GN
Appearance	6.40 B	7.08 A	7.02 A
Color	6.69 B	7.29 A	7.31 A
Flavor	5.54 B	5.77 B	6.35 A
Overall Liking	5.56 B	5.79 B	6.41 A

Values in rows with like letters were not significantly different at (p=0.05)

(STD=standard/control; NV=no vitamins added; GN=partial gum substitution and no vitamins added)

Both samples with optimized formulations (NV and GN) were significantly better in terms of appearance and color. In addition, samples with altered stabilizers and no vitamins (GN) were ranked the best overall and had significantly better flavor compared to NV and control. It should be kept in mind that, although there was no statistical difference, samples with no vitamins (NV) were ranked slightly better than control in terms of flavor and overall liking.

Conclusions and recommendations

Based on results of Phase 1 we can draw conclusions that:

- Spreads produced from young cheese (118 d) toughened faster at 52°C than those from mid (162 d) and old cheddar cheese (207 d);
- Middle aged cheese maintained a better color stability than young and old aged cheeses;
- Spread prepared with old cheese showed emulsion separation at all storage temperatures regardless on length of storage while no or minimal phase separation was observed with young and middle-aged cheese samples;
- All samples with altered stabilizers (carrageenan, low methoxy pectin, xanthan, half of standard mixture) hardened less than control;
- Samples with carrageenan had smooth and more soft texture than samples with any other gum, or even samples with only half of standard gum mixture;
- No particular effect of colorants was detected related to textural changes;
- Samples with paprika oleoresin (PO) darkened less compared to control or those with annatto and apo-carotenal alone; however, PO samples had a slightly pinkish hue;
- Samples with 2% citrates (CIT) hardened significantly more than those with di- and tri-sodium phosphates (LP and control) when stored at 52°C;
- Emulsifying salts did not have effect on color;
- Samples with 10x higher vitamin C concentration rapidly darkened and became rubbery after 6 weeks at 52°C;
- Samples with no vitamins (NV) darkened the least at 52°C, while at 38°C color of 'no vitamins' (NV) samples and those with omission of only vitamin C (VNC) was similar but better than control.

Samples for Phase 2 were produced following conclusions from Phase 1. After evaluation of samples produced based on optimized formulations we can conclude that:

- Samples with no vitamins (NV) and with altered stabilizers and no vitamins (GN) darkened to lesser extent compared to control (STD);
- Samples with optimized formulations were less hard after 6 months at 38°c and after 6 weeks at 52°C compared to control;
- Samples stored at cycling temperatures between 30 and 50°C degraded less than those stored at constant 52°C for the same time;
- In all samples, no emulsion separation occurred and pH and water activity were maintained from initial to final analyses;
- Both samples with optimized formulations (NV and GN) were significantly better in terms of appearance and color compared to standard formulation (control). In addition, samples with altered stabilizers and no vitamins (GN) were ranked the best overall and had significantly better flavor compared to NV and control.

Based on our findings **we recommend removal of vitamin C from formulation of cheese spread.** This would be the fastest, least costly and the most efficient alteration in order to keep quality of the product during prolonged storage and/or storage at elevated temperatures. Additional recommendations are (a) **to eliminate all vitamins from the product**; (2) **to replace half of the standard gum mix with carrageenan**, and (c) **to preferably use cheddar cheese aged between 150 and 170 days.**

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Appendix 1

Figure 1. National Cheese Institute Color Standards

Table 1. L-, a-, and b-values of cheese color standards. Highlighted values are of standards #6-10 acceptable for cheese spread

#	L*`	a*	b*
1	87.93	2.58	26.15
2	84.54	3.17	27.84
3	81.90	7.77	34.66
4	80.29	10.61	38.46
5	77.28	14.08	42.21
6	76.80	16.93	44.15
7	74.81	19.05	47.86
8	73.60	23.16	53.39
9	70.29	24.77	52.39
10	69.00	27.99	58.50
11	66.17	29.30	60.31

Table 2 Codes and descriptions of cheese spread produced at the University of Tennessee

Batch Code	Description
4BCON	Control batch with UT formulation
4CON	Meets military specs, uses 4g ascorbic acid (also control)
CON40	Exceeds minimum ascorbic acid by 10x (40 g added)
VNC	Vitamins A, B1, B6 added, no vitamin C (as ascorbic acid)
NV	No vitamins A, B1, B6, or C added
NCL	Standard formula used, no colorants added
APO	Only APO-8'-carotenal used as colorant in standard formulation
ANT	Only Annatto used as colorant in standard formulation
PO	Only Paprika Oleoresin used as colorant in standard formulation
LMG	Lesser amount of gums used vs. standard formulation
XAN	Xanthan gum used as stabilizer substitute
LMP	Low-methoxy pectin used as stabilizer substitute
CAR	Carrageenan used as stabilizer substitute
LP	Altered ratio of trisodium and disodium phosphates
CIT	Sodium citrate used as emulsifying salt substitute

Stress Test Observations: Vitamins

- Standard formulation using 4 g Ascorbic Acid
- Meets military requirement of 38 mg/pouch

Initial

4CON	L*	a*	b*	Hardness (kg)	Adhesive. (kg)
Initial	78.50	17.67	44.89	1.001	-0.626
1m-4	77.13	19.16	49.75	0.896	-0.599
2m-4	77.65	18.82	48.03	0.707	-0.431
1m-38	73.44	17.82	43.34	1.529	-0.709
2m-38	71.11	17.13	40.80	1.777	-0.767

1 mo. 2 mo.

4°C

38°C

L: 76.80- 69.00
a: 16.93 – 27.99
b: 44.15 – 58.50

Stress Test Observations: Vitamins

- Standard formulation with 10x Ascorbic Acid added

Initial

CON40	L*	a*	b*	Hardness (kg)	Adhesive. (kg)
Initial	77.83	18.86	49.01	1.042	-0.561
1m-4	77.04	19.90	51.97	1.376	-0.822
2m-4	77.31	19.13	49.55	1.299	-0.734
1m-38	69.89	18.77	46.32	1.664	-0.780
2m-38	62.15	16.92	39.16	2.175	-0.708

1 mo. 2 mo.

4°C

38°C

L: 76.80- 69.00
a: 16.93 – 27.99
b: 44.15 – 58.50

Stress Test Observations: Vitamins

- Standard formulation including vitamins A, B1, B6
- No Ascorbic Acid added

Initial

VNC	L*	a*	b*	Hardness (kg)	Adhesive. (kg)
Initial	80.01	18.15	45.83	0.943	-0.54
1m-4	78.18	19.02	49.65	1.045	-0.662
2m-4	78.41	18.90	48.34	0.865	-0.58
1m-38	78.12	18.81	46.30	1.471	-0.934
2m-38	76.94	19.26	46.36	1.819	-0.585

L: 76.80- 69.00
a: 16.93 – 27.99
b: 44.15 – 58.50

1 mo. 2 mo.

4°C

38°C

Stress Test Observations: Vitamins

- Standard formulation excluding all vitamins (A, B1, B6, C)

Initial

NV	L*	a*	b*	Hardness (kg)	Adhesive. (kg)
Initial	80.23	17.32	43.53	1.04	-0.617
1m-4	78.89	18.84	49.08	0.943	-0.684
2m-4	79.56	18.28	46.65	0.763	-0.55
1m-38	78.87	18.18	44.42	1.37	-0.629
2m-38	78.51	18.27	44.87	1.483	-0.595

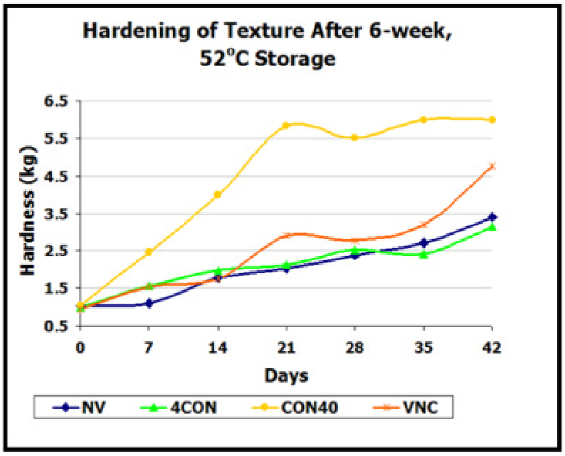
L: 76.80- 69.00
a: 16.93 – 27.99
b: 44.15 – 58.50

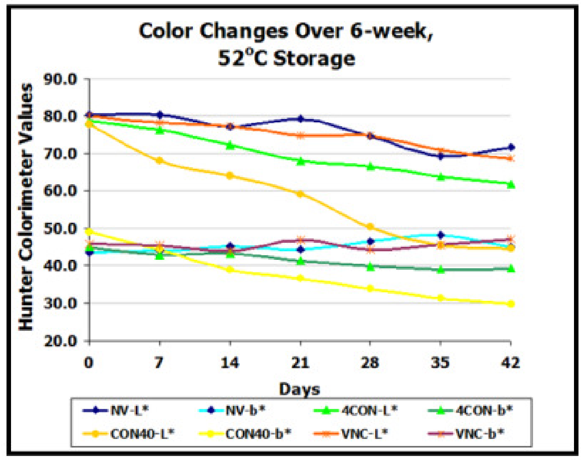
1 mo. 2 mo.

4°C

38°C

'emperature effect on vitamins at 52°C





	NV	VNC	4CON	CON40
Initial				
6-week				

L: 76.80- 69.00
a: 16.93 – 27.99
b: 44.15 – 58.50

Observations after one month storage: Control and no color

- 4BCON: Control batch (using 4g Ascorbic Acid), meets military specs
- NCL: Standard formulation with no colorants added

		L*	a*	b*	Hardness (kg)	Adhesive. (kg)
4BCon	Initial	76.41	20.11	55.14	1.28	-1.061
	1m-4	75.05	21.24	55.26	0.599	-0.457
	1m-38	69.95	19.02	48.02	0.952	-0.531
	4w-52	59.56	20.18	44.84	2.226	-0.633
NCL	Initial	88.59	0.86	17.41	0.881	-0.795
	1m-4	87.19	1.36	18.79	0.343	-0.315
	1m-38	77.15	5.69	22.60	0.643	-0.397
	4w-52	66.50	8.03	24.50	1.66	-0.633

Initial 4C 38C

4BCON

NCL

L: 76.80- 69.00
a: 16.93 – 27.99
b: 44.15 – 58.50

Observations after one month storage: Colorants

		L*	a*	b*	Hardness (kg)	Adhesive. (kg)
4BCon	Initial	76.41	20.11	55.14	1.28	-1.061
	1m-4	75.05	21.24	55.26	0.599	-0.457
	1m-38	69.95	19.02	48.02	0.952	-0.531
	4w-52	59.56	20.18	44.84	2.226	-0.633
ANT	Initial	77.98	16.93	58.37	0.789	-0.777
	1m-4	75.74	18.08	60.97	0.492	-0.376
	1m-38	70.14	17.36	48.56	0.847	-0.416
	4w-52	58.39	19.07	43.97	1.996	-0.62
APO	Initial	77.73	20.22	42.52	0.766	-0.707
	1m-4	75.03	22.41	50.42	0.572	-0.433
	1m-38	75.03	22.41	50.42	0.916	-0.428
	4w-52	59.45	17.85	40.39	2.102	-0.616
PO	Initial	76.69	21.63	37.33	0.916	-0.845
	1m-4	75.03	23.04	44.17	0.52	-0.352
	1m-38	70.03	18.67	34.71	1.055	-0.379
	4w-52	63.92	17.12	34.20	1.869	-0.438

Initial 4C 38C

ANT

APO

PO

L: 76.80- 69.00
a: 16.93 – 27.99
b: 44.15 – 58.50